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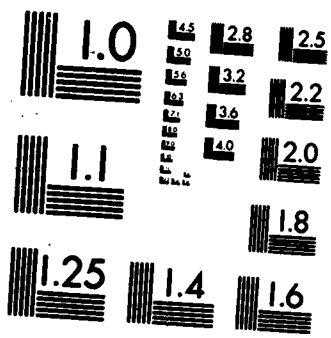

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FATIGUE AND FRACTURE MECHANICS OF

STRUCTURAL METALS, PLASTICS, AND COMPOSITES

prepared by

Richard W. Hertzberg

Grant AFOSR-85-0138

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AFOSR/DOD-URIP funds were used to purchase an Instron computer-controlled mechanical test system for the purpose of evaluating the fatigue and fracture response of metals, plastics, and composites. The FCP Run program provided with the test system has been modified to include differing testing options (constant K_{max} and constant K_{mean} decreasing K threshold procedure) and incorporate stress intensity factor and compliance calibrations for several additional specimen configurations. Experiments have been conducted with both plastics and metals to confirm the unsefulness of the system and the modifications of the software.

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Equipment Acquired

AFOSR/DOD-URIP funds were used to purchase a computer-controlled mechanical test system for the purpose of studying the fatigue and fracture response of metals, plastics and their composites. The specific system contains the following items: Instron model 1350 servo-hydraulic test machine with associated electronics. The latter includes a dynamic waveform analyzer, 5 KIP and 1 KIP load cells, activator self-contained 5 GPM hydraulic power supply, set of loading grips and COD gauge. The computer to be used is the Instron Series V1-23 system based on the DEC PDP 11/23 minicomputer. The computer contains a Winchester hard disk drive and a DEC floppy disk. Also included with this system was a DEC VT240 graphic video terminal with controllers, DEC LA50 printer/plotter. Supporting software was also provided in the purchase price, including the FCP Run program which allows for automated fatigue crack propagation testing of a wide variety of engineering solids.

Acquisition and Installation

Difficulties were encountered regarding delivery of the fatigue test system. The carrier was unable to deliver the equipment during one particular week and proceeded to place the entire shipment in storage for two months without notifying Instron Corporation or Lehigh University. When the system was finally delivered, additional delays were encountered with hardware and software malfunctions. After several months of problem solving, the system was ready for evaluation and use in our research programs.

Summary of Projects Impacted by Equipment

Several programs have already and will make use of new Instron fatigue test system. One project, supported by NSF (Grant DMR-8412357) is concerned with the fatigue crack propagation (FCP) response of PVC as a function of test temperature and frequency. These data will be analyzed in terms of viscoelastic time-temperature relationships. An example of FCP data, generated from the new test system for this material at ambient temperature and at a test frequency of 1 Hz is shown in Figure 1.

Another study being supported by this NSF grant will involve fatigue studies of polymeric material that exhibit nonlinear elastic response. As such, special compliance calibrations are necessary to enable computer-controlled tests to be conducted using compliance crack length measurement procedures. A new set of compliance constants has been determined and will be used with the new PDP 11/23 computer program; the latter allows for the use of arbitrary compliance constants in addition to those associated with standard specimen/material geometries.

Detailed studies are being conducted to re-evaluate the threshold fatigue response of aluminum, steel and nickel-based alloys. These tests will involve variations in testing procedures from the current practice. Instead, of determining ΔK_{th} with K-decreasing methods with constant load ratio, new tests are being planned with the K-decreasing procedure being associated with either constant K_{max} or constant K_{mean} control conditions. Some representative FCP data for 4130 steel that was generated from the new test frame is shown in Figure 2. These threshold analyses are being supported through funds provided by AFOSR (Grant 83-0029) and by the Alusuisse Corporation.

The new test frame was used to generate hysteresis loop characterizations for candidate tank tread materials (polyurethanes). This work was industrially sponsored in cooperation with Watertown Arsenal.

Exploratory studies have begun to evaluate the fatigue response of ultra-high molecular weight high density polyethylene for use in body prostheses.

The new system is being used in conjunction with an optical monitoring device that will allow for automated visual monitoring of advancing cracks in engineering solids.

Software Modifications

The FCP Run software package has been modified with most of the changes being fully de-bugged as of this writing. The basic K-control test procedure with constant mean stress ratio has been expanded to include testing under either constant K_{max} or constant K_{mean} test conditions. Additional stress intensity factor and compliance calibrations have been written and incorporated into the FCP Run program. Current program capabilities include: compact tension, WOL, three-point bend, round compact, arc compact, single edge notch, center-cracked tension, and arbitrary geometry with special calibration coefficients.

A number of other changes have been made to the program to make it more user friendly. For example, it is now possible to undergo an on-line change of control mode to that associated with variable ΔK testing. In this manner it will now be possible to have a smooth transition from the initial start-up test condition to the variable ΔK test procedure rather than exiting the program and restarting. Changes have been made to allow for automatic print-out of load-displacement data for the purpose of the evaluation of crack closure.

The program has been modified to allow for actual crack length readings at a/w levels less than 0.2. This feature is useful during pre-cracking procedures. Prior to this change, the computer recorded a/w values less than 0.2 as being equal to 0.2.

Burst mode data acquisition has been added to all versions of the program which will permit monitoring crack length at frequencies as high as 100 Hz. Valid data checks on inputs to the program were based on English units. These limits have been upgraded to include SI units. Finally, start-up lead factors (initial loading percentage of command load levels) have been increased from 60% to 95% to allow for testing of materials that possess large crack closure levels.

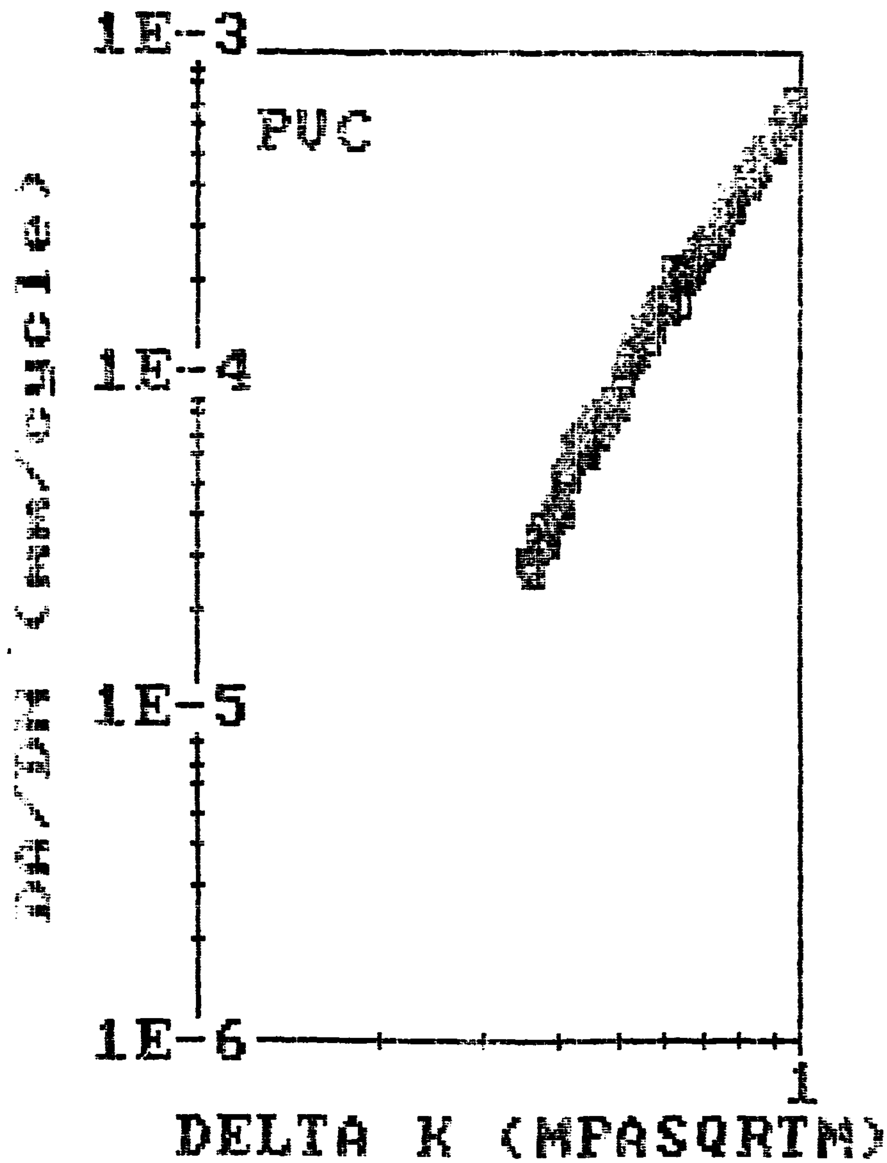

Figure 1.

Fatigue crack propagation data for PVC (room temperature, 1 Hz).

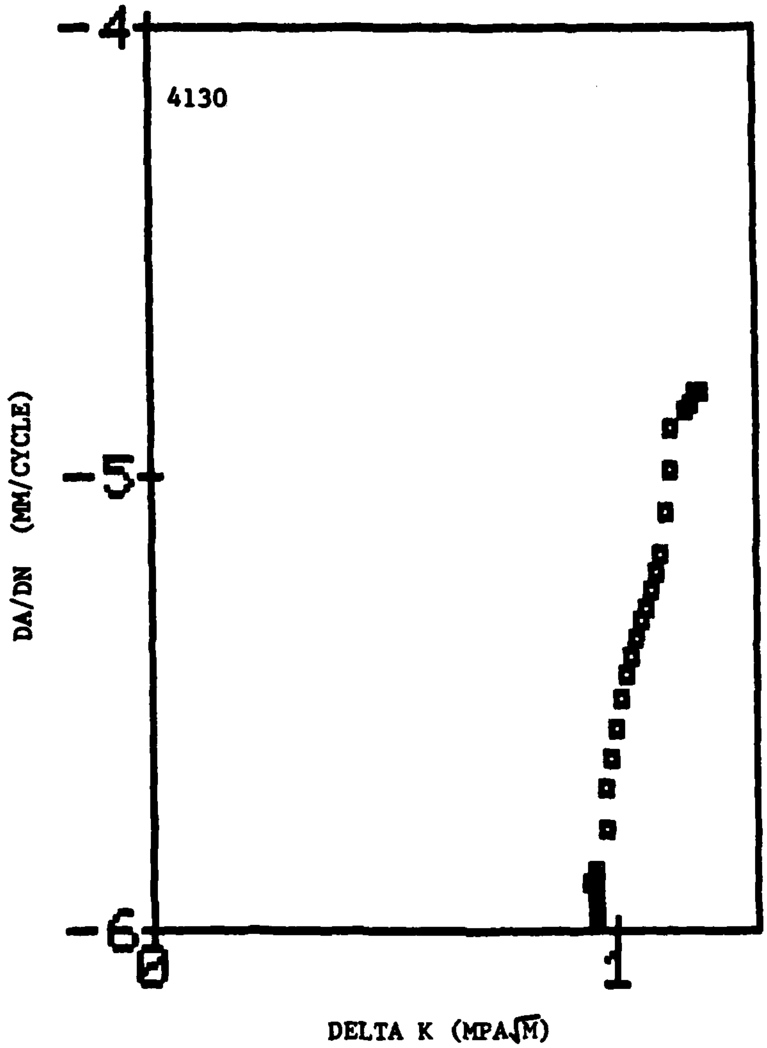

Figure 2.

Fatigue crack propagation data for 4130 steel.
ΔK-decreasing test procedure.

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